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CRITIQUE OF THE GRADIENT/GEOTRANS REPORT ON POTENTIAL CONTAMINANT LOADINGS TO THE NIAGARA RIVER FROM U.S. HAZARDOUS WASTE SITES

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CRITIQUE OF THE GRADIENT/GEOTRANS REPORT ON POTENTIAL CONTAMINANT LOADINGS TO THE NIAGARA RIVER FROM U.S. HAZARDOUS WASTE SITES

Report prepared by:
Monenco Consultants Limited
First Rexdale Place
115 Rexdale Blvd., Suite 500
Rexdale, Ontario
M9W 5Z8

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PART 1

INTRODUCTION

1.1 BACKGROUND

Concern about contaminant loadings to the Niagara River from both point and non-point sources has been raised since the late 1970's. The point source contributors, mainly discharge pipes, have already been identified, and much work has been completed to limit these discharges to the river. Non-point sources, such as landfills, however, have been difficult to identify and quantify.

An initial investigation by the United States Geological Survey (USGS) (Koszalka et al., 1985) identified and summarized the available hydrogeological data on 164 waste disposal sites within three (3) miles of the Niagara River. Gradient Corp. and Geotrans Inc. examined 70 of these individual hazardous waste disposal sites. However, some of these were assumed to be clusters of individual sites, thus further reducing the total to 33 "sites". The locations of these sites are shown in Figure 1-1. The selection process was based upon criteria which were designed to include those sites which present the greatest potential for chemical loadings to the Niagara River. Factors considered during this site selection process included the proximity of the site to the Niagara River, or its tributaries, the types and amounts of waste at each site, the potential for contaminant migration from the site, the availability of site-specific data, and the judgement of the Environmental Protection Agency (EPA) and/or the New York State Department of Environmental Conservation (NYSDEC) personnel.

Gradient Corp and Geotrans Inc. calculated ground water loadings to the Niagara River by multiplying the contaminant concentrations in the groundwater by the estimated groundwater flow rates. Contaminant concentrations for each of the sites were based on either the sum of the contaminants detected in the ground water on the site or a concentration value determined by a formula based solely upon Total Organic Carbon (TOC) and Total Organic Halogen (TOX). Groundwater

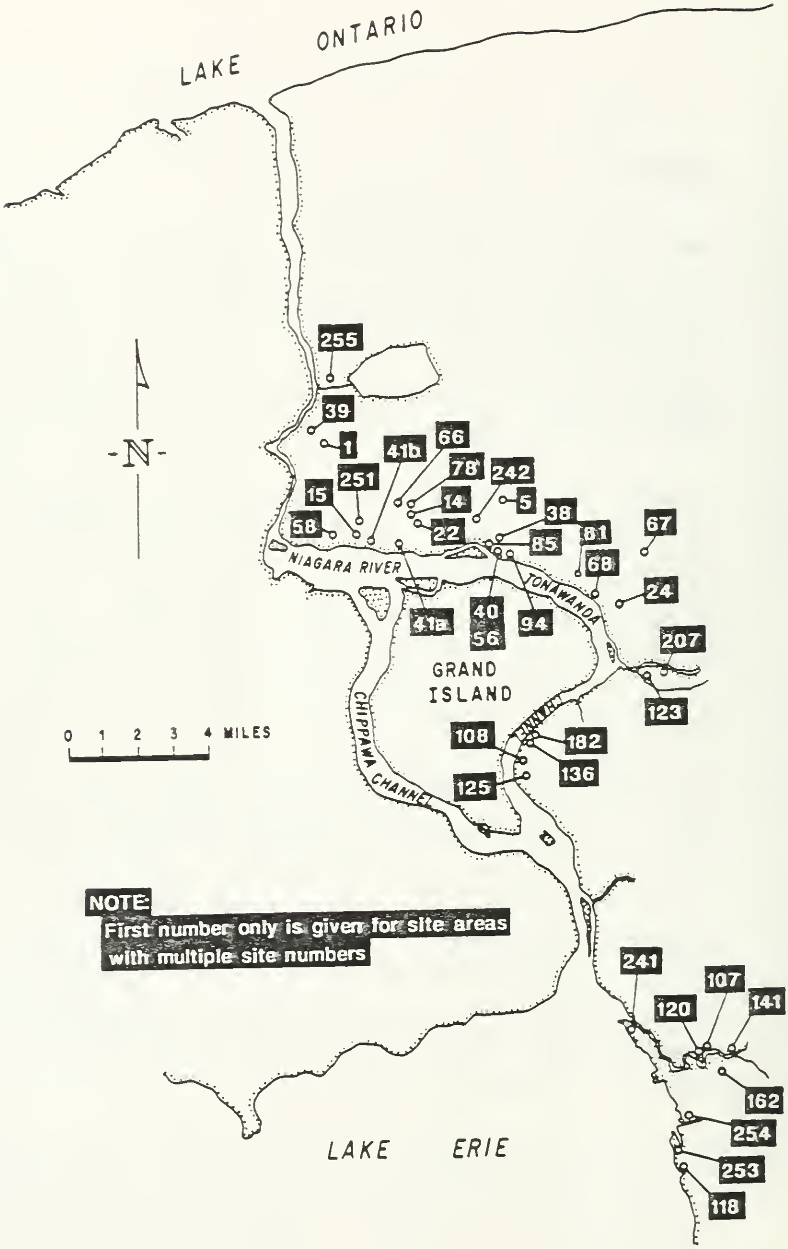


FIGURE 1-1 Locations and USGS site numbers of the 33 hazardous waste sites investigated by Gradient Corp. and Geotrans Inc.. (From Gradient and Geotrans)

flow rates were estimated by three methods: application of Darcy's Law, water budget calculations, and flow models.

1.2 TERMS OF REFERENCE

The Ontario Ministry of the Environment (MOE) issued a Request For Proposal in June, 1988 to evaluate the methodology of the Gradient/ Geotrans report. Monenco Consultants Limited was retained to perform the study, based upon the Terms of Reference summarized below:

1) The Consultant shall review the report entitled "Potential Contaminant Loadings To the Niagara River from U.S. Hazardous Waste Sites", dated February 29, 1988 and produced for the United States Environmental Protection Agency by Gradient Corporation and Geotrans Inc.

2) The Consultant shall assess the methodology for validity and identify all assumptions that were made in the analysis and determine the error margin if each assumption was incorrect.

3) The Consultant shall evaluate the method validity for the reduction of the number of sites from 164 within three (3) miles of the Niagara River to 70 (33 clusters).

4) The Consultant shall evaluate, in detail, the calculations and conclusions made with respect to all sites in the group of 70 that currently are listed on U.S. EPA's National Priority List, along with CECOS's RCRA permitted facility.

5) The Consultant shall present conclusions as to the validity of the entire method of loadings determination and present recommendations as to how the confidence level could be improved and what steps could be taken as follow-up measures to the Gradient/Geotrans report.

6) The Consultant shall generate a report for Phase I which includes the results of tasks 1) through 5) inclusive.

1.3 GRADIENT/GEOTRANS APPROACH

The approach used by Gradient Corp. and Geotrans Inc. to calculate the potential loading from each site to the river involved the estimation of groundwater contaminant concentrations based on available chemical analyses at the downgradient site boundaries and the estimation of groundwater flux in all hydrostratigraphic units at each site. The contaminant concentration in the groundwater multiplied by the groundwater flux was then taken to equal the potential contaminant loading to the Niagara River.

For all calculations, potential loadings were determined by Gradient Corp and Geotrans Inc. from "high", "best", and "low" estimates of both contaminant concentrations and groundwater flow rates. The estimates of potential loadings were then reduced by a differential factor to account for attenuation. The attenuation factor was chosen for each site in an arbitrary manner in decrements of 25% of the potential loadings. The specific percentage reduction chosen reflected the site's proximity to the Niagara River, or nearest tributary, the quality and age of the site-specific data, and the judgement of Gradient/Geotrans personnel. This value was then used as the best estimate of the contaminant loading from the groundwater to the Niagara River.

1.4 PROBLEMS OF APPROACH

There are several problems associated with continuity of approach in the Gradient/Geotrans report. The groundwter and soil data were collected by consultants, industry, and government; and analysed by several different laboratories for different parameters, with varying detection limits. This then results in data incompatibility because of different sampling protocols and laboratory standards from site to site. These problems are difficult, if not impossible to rectify, because of the number of sites involved. One single agency or consultant could not investigate all of the sites in the allocated time frame. The only reasonable alternative would have been to have the EPA, or some other agency, initiate a set of protocols for groundwater and soil monitoring in order to ensure some consistency in data collection.

Interference between sites is a problem where some sites are so close together that the individual effects are probably not determinable. Consequently, Gradient and Geotrans treated these sites as a "group" loading. This should not affect the results, since data from all of the individual sites were still considered. The only problem with this approach is that it does not distinguish which individual sites within the clusters are the most significant contributors to the overall loading. The loadings may be overestimated due to double counting of contaminant loadings on some properties adjacent to the Niagara River because of flow-through from upgradient sites.

Data confidentiality and limited distribution of data both result in gaps in the database. Furthermore, many investigations were in progress at the time of publication of the Gradient/Geotrans report due to the relatively recent increase in concern about the environment. As a result, pre-1984 data were used by Gradient Corp. and Geotrans Inc. in some cases because recent data could not be obtained. Consequently, some contaminant discharges may be overestimated, since remedial measures to reduce off-site migration were recently implemented at a few sites

The estimation of contaminant loading from groundwater by multiplying flux times concentration is valid, but the methods used by Gradient screening/indicator parameters, where TOX provides an indication of the organic halogens present in mg/L of chlorine and TOC provides a measurement of all organic compounds present in mg/L of carbon. However, these are only approximations and can be in error by as much as (+/-) 100%. Further details are provided in section 3.2.3.

This equation was also used on two properties (Olin, Buffalo Avenue and Columbus McKinnon) where four alternate analyses were performed (ie Total Halogenated Organics - THO, Total Volatile Halogenated Organics-TVHO, Halogentated Organic Scan-HOS and Volatile Halogented Organic Scan-VHOS). All four of these alternate analyses are Gas Chromatography/Mass Spectroscopy (GC/MS) scans which report the actual concentration of the compound in ppb compared to the TOX analysis which reports the concentration in ppb chlorine. In these cases assumptions were made that the sum of the THO and TVHO or the sum of HOS and VHOS represented the TOX value, and also that the TOC value equalled the TOX value. No data were given to support these assumptions. Furthermore, there is no basis for the direct comparison of the concentration of specific compounds from GC/MS data and the results of a TOX analysis. Also, on average for the 33 sites studied, the TOC values do not equal the TOX values. A complete summary of the data, including the TOC, TOX, and calculated concentrations is provided in Appendix A. A full evaluation of the equation and possible modifications are suggested in section 3.2.2. herein.

The problems discussed above could result in both determinate and indeterminate errors. Determinate errors are the result of identifiable biases such as the use of an incorrect formula. These errors are cumulative, and therefore increase in magnitude as the statistical sample size increases. Indeterminate errors, such as analytical errors, are random, and tend to cancel out with larger sample sizes. It is the determinate errors therefore, which should be eliminated first.

statistical sample size increases. Indeterminate errors, such as analytical errors, are random, and tend to cancel out with larger sample sizes. It is the determinate errors therefore, which should be eliminated first.

PART 2

SITE ELIMINATION CRITERIA

2.1 SITE SELECTION

The Gradient/Geotrans report initially considered 164 sites within three (3) miles of the Niagara River. The three (3) mile distance was not explained in this report, or in any other report made available to Monenco. Sites in Niagara and Erie Counties were initially inventoried by the Interagency Task Force (comprised of personnel from NYSDEC, New York State Department of Health and the U.S. EPA). The USGS studied these sites, and concluded that 61 had "major" potential for migration, while an additional eight (8) sites were noted as having "limited" potential for migration or possible hydraulic connection to the Niagara River (Koszalka, 1985). A total of 26 sites either could not be accurately located, or did not involve hazardous materials. The other 68 sites were described as having "indeterminate" potential.

When deciding which sites to include in the loading calculations, Gradient Corp. and Geotrans Inc. had to make several assumptions regarding the significance of the contaminant contribution. A list of these assumptions is provided in Table 2-1. Gradient Corp. and Geotrans Inc. started with the 69 sites highlighted by the USGS report as having "major" or "limited" potential for contaminant migration. Of the resulting 69 sites, Gradient Corp. and Geotrans Inc. decided that the data were inadequate for seven (7) sites, and therefore deleted them from the study, thereby reducing the number of sites to 62. The data presented by Koszalka et al. (1985) for these seven (7) sites are provided in Appendix B. Another eight (8) sites from the initial 164 were added on the basis of new data collected after the USGS report was issued in 1985, thereby increasing the number of sites to 70.

In order to simplify the calculations and eliminate the problems created by interferences, some of the individual sites were grouped as clusters by Gradient Corp. and Geotrans Inc., and evaluated

Table 2-1 List of Assumptions in the Gradient/Geotrans Report Involving Site Elimination Criteria

ASSUMPTIONS	COMMENTS	TYPE OF ERROR	MARGIN OF ERROR
Only sites within 3 miles of the Niagara River were considered	other sites could be be significant	determinate	large
Sites were grouped into clusters, instead of calculations based on individual sites	reasonable assumption	indeterminate	moderate
If a site could not be accurately located, it was not a significant contributor	could remove a significant site from consideration	determinate	large
If data were not deemed sufficient for analysis the site was dropped; the implicit assumption is that a site lacking good data isn't a problem.	significant sites may not have been investigated	determinate	large

together. This "cluster" approach was discussed in section 1.4, and should not result in serious errors.

The methodology described above is the only feasible way Gradient Corp. and Geotrans Inc. could have limited the analysis to the sites of greatest concern. Since this study did not involve any field programs, sites having insufficient data for proper analysis could not be considered. It is possible, however, that one or more of the 94 sites that were not examined by Gradient Corp. and Geotrans Inc. may be a significant source of contaminants. As well, it is possible that there are sites beyond the three (3) mile limit, but still within the Niagara River watershed that are contributing loadings to the river by way of minor streams (possibly intermittent) and man-made conduits. A high priority should be placed on ensuring that all of the sites contributing contaminants to the Niagara River are identified.. After all of the significant waste site contributors of contaminant loadings have been determined, a program detailing remediation procedures for all sites can then be completed. An initial priority list of the U.S. hazardous waste sites within three (3) miles of the Niagara River is provided in Appendix C.

PART 3

CONTAMINANT LOADING CALCULATIONS

3.1 INTRODUCTION

Gradient Corp. and Geotrans Inc. estimated contaminant loadings by multiplying the average pollutant concentration by the groundwater flux through each of the hydrostratigraphic units. The formula used to calculate the loadings was:

$$L = C \times Q,$$

where: L = loadings
C = concentration (ppb)
Q = volume flux of groundwater (gal/day)

The contaminant concentrations were either estimated from the average of the individual analyses, or computed from an equation based upon TOX (Total Organic Halogen) and TOC (Total Organic Carbon). Inorganic contaminants were not specifically discussed except for selected sites where high concentrations of specific contaminants were observed. Background corrections were not performed. For sites where TOX and TOC analyses were available, the average contaminant concentration was calculated according to the following formula:

$$\text{Average Concentration "C"} = [\Sigma(\Sigma c_i)_j]/n$$

where: c_i = concentration of constituent "i" in well "j"
n = number of wells

Volume flux was estimated from Darcy's Law for bedrock, water budget for overburden, and flow models where available for both bedrock and overburden. Details of each of these methods are provided in the following sections. A summary of the assumptions in the overall loading (L) methodology is provided in Table 3-1.

Further details on contaminant concentrations (C) and groundwater flux (Q) are provided in sections 3.2 and 3.3 respectively.

Table 3-1 List of Assumptions in the Gradient/Geotrans Report Concerning the Overall Loadings Estimate

METHODOLOGY	ASSUMPTIONS	COMMENTS	TYPE OF ERROR	Margin of ERROR
LOADING: $L = C * Q$ where: C = Concentration, Q = Volume Flux	100% of the potential loading was assumed to be the actual loading for sites adjacent to the Niagara River or a tributary; lower values were used away from the River (arbitrary divisions were used to allocate the actual loadings into 25%, 50%, or 75% of the potential loadings	arbitrary factor	indeterminate	large
CLUSTERING OF SITES	70 individual sites were grouped into 33 clusters	individual site effects difficult to determine	indeterminate	small

3.2 CONTAMINANT CONCENTRATION CALCULATIONS

3.2.1 Assumptions

The determination of contaminant concentrations by Gradient Corp. and Geotrans Inc. comprised assumptions related to; ratio of organic halogen to organic carbon, absence of inorganic contaminants, minimum background variability, equality of data and laboratory detection limits. A summary of these assumptions is provided in Table 3-2.

3.2.2 Statistical Significance

Statistical methods and validity are not discussed in the Gradient/Geotrans report. With the very low values reported for the chemical concentrations, and the relatively few analyses, it is quite possible that the concentrations may not be statistically significant relative to background levels. Without the duplicate and the background well concentrations as well as the trip blanks and spiked samples (data not available to Monenco), no statement can be made about the statistical validity of the data.

Determining the central tendency of hydrogeologic data can be quite complex. In most hydrogeological investigations, the chemical data are averaged, but other methods can be used. For example, Gradient Corp. used the average, or arithmetic mean of the contaminant concentrations across the downgradient boundary. Where nested wells were present, the nests were averaged together before being averaged with neighbouring wells (Shifirin, 1989). This statistic is calculated as follows:

Table 3-2 List of Assumptions in the Gradient/Geotrans Report Concerning Concentration Estimates

METHODOLOGY	ASSUMPTIONS	COMMENTS	TYPE OF ERROR	MARGIN OF ERROR
TOX/TOC FORMULA: $C = 2.6*TOX + 0.4*TOC$ where: TOX = Total Organic Halogen TOC = Total Organic Carbon	38% chlorine and 49% carbon content, by weight; carbon/chlorine ratio = 1.4	no certainty that all of the 229 chemicals used to generate the equation are present at any site and in the same proportions; the chlorine/carbon ratio varies among different organic chemicals	determinate	large
	only considers organic contaminants	of the measured, in-stream loadings, iron and aluminum account for 98%, trace metals contribute 2%, while organics represent <0.01% (NRTMP, 1987)	determinate	large
	2/3 of non-halogenated hydrocarbons (TOC) are natural	ignores local background variability of TOC values	determinate	large
	THVO+THO = TOX or HOS+VHOS = TOX and TOC = TOX where: THVO = Total Halogentated Volatile Organics THO = Total Halogenated Organics	other related analyses (THVO THO, HOS and VHOS) were used as substitutes for TOC and TOX, where these values were not available	determinate	moderate

Table 3-2 (continued)

METHODOLOGY	ASSUMPTIONS	COMMENTS	TYPE OF ERROR	MARGIN OF ERROR
	HOS = Halogentated Organic Scan VHOS = Volatile Halogenated Organic Scan			
SUM OF AVERAGE CHEMICAL CONCENTRATIONS	iron and aluminum considered to be background	Ignores industrial sources of these parameters	determinate	large
DATA COMPILATION	All data treated equally	Different laboratory methods/ reliability and field techniques ignored	determinate	large
	No data: site not significant	No new data collected	determinate	moderate
	limited data: boundary + interior wells assumed to be representative	including highly contaminated wells in the waste areas may overestimate the extent of contamination	determinate	moderate
	Some data: boundary wells assumed to be representative	reasonable assumption	determinate	small
	Complete data: Selected downgradient wells assumed to be representative	selecting some downgradient wells could underestimate the contaminant concentration.	determinate	moderate
DETECTION LIMITS	Detection limits assigned to parameters detected on-site, but not found in a particular well	conservative approach (overestimate)	determinate	large

$$\bar{X} = \frac{X_1 + X_2 + X_3 + \ldots}{n}$$

where: $\bar{X}$ is the mean,
X_1, X_2, X_3 are contaminant concentrations
n is the number of analyses

This statistic is suitable if the chemical concentrations exhibit a normal distribution (see Appendix D for examples of normal and non-normal distributions and calculated values of selected statistics). However, chemical concentrations tend to exhibit skewed normal or log-normal distribution. This is due to the low values observed for organic contaminants in groundwater studies, which are close to, but never less than zero. For example, compounds that were not detected were found as significant contributors to the loadings calculations for 18 of the 33 sites, according to estimates made by Gradients Inc. If the statistical distribution of the chemical data is not "normal" the arithmetic mean may not be representative of the true central value.

The geometric mean, which is expressed as:

$$\bar{X} = (X_1 \times X_2 \times X_3 \times \ldots)^{1/n}$$

results in a lower value than the arithmetic mean, but provides a better estimate of the central tendency than the mean, if the data are skewed or are not normally distributed (Myers, 1989). Another approach could be to use the median, which can also be used for non-normal distributions (Myers, 1989). Diagrams showing the differences between the mean and median are provided in Appendix D. The difference between the mean and median can be (+/-) 100%, depending on the distribution of the data.

3.2.3 The TOX/TOC Formula

Gradient Corp. used a formula based upon TOX and TOC. These two parameters are normally used as screening/indicator parameters to identify areas of severe contamination (Feentstra, 1987). With TOC analysis, background levels are sometimes high enough to "mask" a contaminant plume while TOX analysis is subject to interferences from inorganic chloride, a common component of landfill leachate (Feenstra, 1987). TOC provides a measurement of all organic compounds present (natural and contaminants) in the sample, usually in mg/L as carbon. This value cannot be compared to the summed concentrations of all the compounds found in a GC/MS scan, because the result is given in mg/L as carbon, while GC/MS data are given in mg/L as the compound of interest (Feenstra, 1987). Data from Feenstra (1987), provided in Table 3-3 illustrates this problem in using TOC as a substitute for a GC/MS scan. The possible error from this use of TOC analyses may be (+/-) 100%.

Table 3-3 Comparison of Chemical-specific Concentrations to Equivalent Organic Carbon Concentrations

Chemical	Concentration	
	Actual (mg/L)	TOC (mg/L as C)
Hexachloroethane	10	1.0
Trichlorophenol	10	3.7
Nitrobenzene	10	5.9
Naphthalene	10	9.4
SUM	40	20.0

TOX provides an indication of the organic halogens present in a sample in mg/L as chlorine. The same problem of comparing TOC with a GC/MS scan applies to TOX. For example, consider the data in Table 3-4, from Feenstra, 1987. The result may be an error of

(+/-) 100%.

Table 3-4 Comparison of Chemical-specific Concentrations to Equivalent Organic Chlorine Concentrations

Chemical	Concentration	
	Actual (mg/L)	TOC (mg/L as Cl)
Chloroform	10	9.1
Trichlorophenol	10	5.5
2-Chloronaphthalene	10	2.2
Chlorobenzene	10	3.2
SUM	40	20.0

The TOX/TOC formula used by Gradient Corp. for estimating the contaminant concentrations is as follows:

$$C = \frac{TOX}{0.38} + \frac{TOC}{0.49}$$, which simplifies to:

$$C = (2.63 \times TOX) + (2.04 \times TOC) \qquad (A\text{-}1)$$

Gradient Corp. then assumed that the overlap of chlorine and carbon on the same molecule can be expressed as:

$$\frac{C}{X} = \frac{0.49}{0.38} = 1.4 \qquad (A\text{-}2)$$

Therefore, Gradient Corp. reduced the TOC coefficient by 40%. This results in a modified equation, as follows:

$$C = (2.63 \times TOX) + (1.22 \times TOC) \qquad (A\text{-}3)$$

The last assumption that was made involved "natural contamination". Gradient Corp. assumed that 2/3 of the non halogenated carbonaceous material accounted for in the TOC analysis was due to natural compounds such as humic and fulvic acids. This assumption may not be valid. The Hyde Park Landfill, for example, has a background TOC concentration of 3000 ppb while the average TOC in the wells used in the analysis was 8,871 ppb (data provided in the Gradient/ Geotrans report). Equation A-3, then was modified by reducing the TOC coefficient by a factor of 2/3. The final formula then became:

$$C = (2.6 \times TOX) + (0.4 \times TOC) \qquad (A\text{-}4)$$

The formulae above assume average chlorine and carbon contents to be 38% and 49% respectively (by weight). These percentages were derived by Gradient Corp. from a database of 229 organic compounds, including priority pollutants. The formula, however, does not account for 13% of the halogenated hydrocarbon mass. The other 13% (by weight) is assumed to consist of other elements such as nitrogen and hydrogen. A possible modification to account for the other 13% could be to assume that the concentration "C", above, represents only 87% of the total hydrocarbon mass.

$$0.87 \times C = (2.63 \times TOX) + (2.04 \times TOC) \text{ or,}$$

$$C = 3.02 \times TOX + 2.34 \times TOC \qquad (B\text{-}1)$$

If the assumptions regarding TOX/TOC overlap and background TOC (2/3 of the non-halogenated hydrocarbons) are maintained, the formula becomes:

$$C = 3.02 \times TOX + 1.1 \times TOC \qquad (B\text{-}2)$$

The difference between equation B-2 and the Gradient Corp. formula (equation A-4) is proportional to the TOX/TOC ratio, since the allowances for overlap of chlorine and carbon and "natural" contamination affect only the TOC value.

Appendix A provides a tabulation of the chemical analyses, including TOX, TOC and the sum of the average contaminant concentrations for each of the sites examined by Gradient Corp. and Geotrans Inc. A summary is provided in Table 3-5 below.

Table 3-5 Summary of the Gradient/Geotrans Concentration Estimates

	Sum of Avg. Conc. (ppb)	TOX (ppb)	TOC (ppb)	TOC/TOX	Conc. from Formula A-4 (Gradient) (ppb)	Conc. from FormulaB-2 (Monenco) (ppb)
high	660,000	205,000	1,250,000	1,577	1,033,280	2,031,770
low	$4x10^{-1}$		2,000	$8x10^{-4}$	803	2,203
average	36,100	7,892	59,850	8	44,460	91,090

Note: Data from all 33 site areas studied by Gradient Corp. and Geotrans Inc.

Because the TOX/TOC formula is based upon a group of specific contaminants, the formula may not apply to sites with contamination from a few or none of the contaminants in the list. This is due to the inherent variation in the chlorine/carbon ratio in halogenated organic compounds. The implicit assumption in the Gradient/Geotrans report is that the chemicals found on each individual site have the same average carbon and chlorine content as the established database. No attempt was made in the report to statistically validate this assumption.

Without copies of the analyses used in the calculations, which were not available to Monenco, it is not possible to estimate the error on the validity of this assumption. Another problem with this equation is the large margin of error involved in the TOX and TOC are significantly greater than the detection limits for various individual organic compounds, significant contamination by a single compound may not be distinguishable by TOC and TOX analyses alone.

The use of GC/MS scans such as as THO (Total Halogenated Organics), TVHO (Total Volatile Halogenated Organics), HOS (Halogenated Organic Scan) and VHOS (Volatile Halogenated Organic Scan) as alternative analyses to the TOX analysis on two (2) sites where TOX and TOC were not available also affects the certainty of the concentration calculations. For these sites the TOX value was inferred from the sum of THO and TVHO or HOS and VHOS, and the TOC value was assumed to be equal to the estimated TOX value. Neither of these assumptions was verified. As can be seen from the data in Tables 3-3 and 3-4, direct comparisons of TOX and TOC with GC/MS scans (such as THO, TVHO, HOS and VHOS) may be invalid, depending on the compounds present. From the data in Appendix A (summarized in Table 3-5), the average TOC value was eight (8) times higher than the average TOX value. Therefore, the calculations based on these analyses may be invalid.

3.3 GROUNDWATER FLUX CALCULATIONS

3.3.1 Assumptions

Any type of groundwater flux calculation based on regional data collected from many sources may be a gross estimate at best. Geotrans Inc., which performed the groundwater flux calculations for the Gradient/Geotrans report, used the following three methods:

- Darcy's Law
- Water Budget
- Groundwater Models

Darcy's Law is used in most hydrogeological studies, since it is one of the easiest methods to apply, and the results are considered to be of reasonable accuracy, given the inherent uncertainties involved in subsurface investigations. This method was used for calculating the groundwater volume flux in bedrock by Geotrans Inc., unless flow models were available.

The water budget method, which was used for the overburden volume flux estimates, is another common procedure for estimating volume flux. This approach was used instead of Darcy's Law, because the variables used (ie. precipitation, infiltration, evapotranspiration, etc) exhibit less variation than the hydraulic conductivity used by the Darcy's Law method.

Flow models were used, where available, to replace the analytical calculations involved with the Darcy's Law and water budget estimates. Numerical models involve the same basic assumptions as the other methods, but can incorporate conditions which cannot be solved analytically.

A summary of the assumptions used in these three methods described above is presented in Table 3-6 and additional details on each of the methods are provided in the succeeding text.

3.3.2 Darcy's Law

Darcy's Law states the groundwater flux (Q) is:

$$Q = (k)(i)(A),$$

where:

k = hydraulic conductivity
i = groundwater gradient
A = cross-sectional area perpendicular to the flow.

Generally speaking, these estimates are accurate only to (+/-) 0.5 order-of-magnitude, since "i" and "A" can be defined with reasonable accuracy, and "k" can only be measured to an accuracy of (+/-) 0.5 order-of-magnitude. However, due to the highly variable groundwater gradients in this area caused by the raising and lowering of the water levels above the power plants on the Niagara River, the effect of the gorge itself on gradients near the River, and the presence of buried utility corridors, groundwater flow gradients may be difficult to predict. This, combined with the relatively few measurements conducted at each site creates a high degree of uncertainty in the data.

3.3.3 Water Budget

The water budget approach is probably as accurate as the Darcy's Law approach. Recharge rates, as estimated from long term precipitation records, and estimates of run-off and infiltration, may exhibit less variation than the hydraulic conductivity, but these parameters were not measured. Since the values are assumed, as opposed to the measured "k" values, this estimation method may only be as accurate as Darcy's Law. The assumptions must be made that the infiltration is uniform across the entire region. Since this area is covered by a variety of soil types, clay covers, impermeable pavement and

Table 3-6 List of Assumptions in the Gradient/Geotrans Report Concerning Groundwater Flux Estimates

METHODOLOGY	ASSUMPTIONS	COMMENTS	TYPE OF ERROR	MARGIN OF ERROR
DARCY'S LAW		Common method of data interpretation	indeterminate	moderate
Q = k x i x A where: k = permeability i = gradient A = Area	"k", "i" and "A" can be accurately measured	"k" can only be estimated to (+/-) 1/2 order-of-magnitude	indeterminate	moderate
		"i" may exhibit local and or temporal variation due to diversions by power companies causing (+/-) 2 metre variations in river level	indeterminate	moderate
		"A" can be determined accurately	indeterminate	small
RECHARGE	recharge data/ regional data used in place of site-specific data	site-specific data not available	indeterminate	moderate
	overburden flow rate used where bedrock flow rate not known (some sites only)	Estimated bedrock values should have been used from other sites	determinate	moderate
FLOW MODELS	no assumptions were stated	Examples of flow models were not provided	indeterminate	moderate

buildings, this assumption is questionable. In addition, the assumed recharge values cannot be applied to bedrock flow regimes where there is a significant flow-through from upgradient sources unless the wastes are in contact with the bedrock groundwater. Since recharge rates are not easily determined, values were assumed by Geotrans Inc. as follows:

low: 3 in/yr | - for waste/fill, alluvium,
best: 9 in/yr | silt and sand
high: 15 in/yr |

low: 1 in/yr | - for clayey silt and silty
best: 5 in/yr | clay
high: 9 in/yr |

The values are reasonable, and correspond to values used by Monenco and other consultants in Southwestern Ontario for a variety of natural soil conditions. However, the amount of industry and paved areas covering the native soils reduce the natural infiltration and there is no guarantee that any site exhibits the assumed values. For example, underdraining of industrial areas could result in an underestimation of loading, while paving, which would reduce infiltration, would cause the loading estimate to be overestimated. No testing was performed to verify that the assumed values are valid for this region. The error involved is determinate, but may not be cumulative, since some sites may be overestimated, while others may be underestimated.

3.3.4 Flow Models

The use of flow models was discussed by Geotrans Inc., but no explanation of their models is given. Numerical models can be more complex than analytical models and incorporate variables which cannot be handled analytically, but they still involve estimations of permeability and recharge values. Also, parameters for flow models are usually defined by laboratory testing instead of being field-determined. Without a description of the model used it is impossible to evaluate the assumptions used in this type of analysis, or the potential errors associated with those assumptions.

Since models from Geotrans Inc. as well as other sources were used, some simple cross-checks by analytical methods could ensure the applicability of a particular model. In the future, if groundwater models were tested and evaluated by a group such as the U.S. EPA, it could be possible to compare the calculated values between sites, and also to compare the model results to analytical methods.

3.3.5 Comparison of Methods for Estimation of Flux

All of the three methods used by Geotrans Inc. have specific advantages and disadvantages. The parameters in Darcy's Law can be measured, but there is a fair degree of uncertainty in the determination of "k", and for those sites close to the Niagara River "i" may be highly variable due to river regulation. Recharge rates involve parameters with less variation than Darcy's Law. For example, precipitation rates are well defined and run-off cannot exceed precipitation. Since Geotrans Inc. allowed a range of values for infiltration between 1% and 50% of the precipitation rate for the region, the high and low estimates should span the true value. Flow models can be very useful in estimating flow directions and rates, but the calculations rely on the measurements of the same parameters used in the other two methods. Also, it is possible to have computational errors in the result that cannot be determined, since the calculations cannot be performed analytically. One solution could be to use only approved models, which have been checked against other programs, and with analytical data. Analytical solutions may not be able to replicate numerical estimations, but can identify large errors.

PART 4

DETAILED LOADINGS CALCULATIONS

4.1 INTRODUCTION

Five sites that are currently on the National Priority List, as well as CECOS's facility were checked to ensure that Gradient Corp. and Geotrans Inc. performed the calculations properly, as per the terms of reference in the MOE's RFP. These calculations agreed with those computed by Gradient Corp. and Geotrans Inc. within (+/-) 1 lb/day. The individual site calculations are provided in Appendix E. The six sites were:

- Occidental Chemical, Love Canal (USGS site #38)
- Occidental Chemical, Hyde Park (USGS site #39)
- Occidental Chemical, 102nd Street (USGS site #40,56)
- Occidental Chemical, S-Area (USGS site #41a)
- Necco Park and CECOS (USGS site #78a, 78b)
- Niagara County Refuse Disposal (USGS site #81)

Of these six properties, only Occidental's S-Area site and the CECOS facility are currently active. All of the others are now closed. Recalculation details and inherent problems with the data sets are provided in the following text.

4.2 OCCIDENTAL CHEMICAL, LOVE CANAL (USGS SITE #38)

Gradient and Geotrans Inc. did not evaluate this site, because of remedial measures, which were believed to have isolated the site from the Niagara River. Since no calculations were performed for this site, no comment is required.

The conclusion that contaminant migration through the overburden has ceased is supported by the maps showing hydraulic containment in the appendices of the Gradient/Geotrans report. Vertical migration into the bedrock is unlikely, due to the very low permeability of the clay and till soils underlying the burial site. There is debate however, regarding the thickness of the overburden soils. The cross-sections in the Gradient/Geotrans report indicate that approximately 7.5 m of overburden exist below the waste, primarily till and soft clay. If this overburden is thinner in some areas, contaminant migration to the bedrock could occur.

The significant item which was not accounted for at this site is the time lag factor. Remedial measures were in place by 1979 at this site, including a barrier wall and a leachate collection system. However, even if all of the leachate migration from the site was stopped, the pre 1979 leachate migration from the property could be impacting the Niagara River presently. Given the range of hydraulic conductivity values (0.004 to 3 metres/day) in the report, it can be calculated that leachate could take from 0.4 to 5500 years to migrate the 360 metre distance to the Niagara River. These values could be higher for Non-Aqueous-Phase-Liquid (NAPL) components, such as oils, which flow at a slower rate than the groundwater. Therefore, it is quite possible that leachate is still entering the Niagara River from this site. No data were supplied to detail the extent of the leachate plume, which would be required to assess whether or not pre-1979 contaminants from the Love Canal site are still entering the Niagara River.

4.3 OCCIDENTAL CHEMICAL, HYDE PARK (USGS SITE #39)

The calculations appear to be valid for this site. A detailed review is given in Appendix E. The loadings, as recalculated, agree with the Gradient/Geotrans figures by a factor of (+/-) 1 lb/day.

The historical data, though dated (1984), appear to be complete, since this site has been thoroughly examined by several consultants over a period of years. The 1984 data may overestimate the current loadings, since some remedial measures including capping of the site and the installation of an overburden drain were initiated to control leachate migration. This is supported by the comment in the Gradient/Geotrans report that "For many parameters, a downward trend has been observed since 1984".

The "gorge face seeps" represent an excellent opportunity to measure true concentrations entering the river. Although the seeps are now concealed behind rubble piles and fences, they are still accessible for sampling. This is the only site of the 70 studied studied by Gradient Corp. and Geotrans Inc. which includes contaminant concentrations of direct discharges into the Niagara River. The Gradient/Geotrans report mentions that some compounds were not analyzed at the gorge face. A sampling round that includes the other parameters could quickly determine whether or not any are actually present. The overall loadings calculation appears to be valid, and is probably a conservative estimate. A summary of the contaminant loading calculations is provided in Table 4-1.

Table 4-1 Summary of Monenco's Contaminant Loading Calculations for Occidental Chemical's Hyde Park Site

Parameter	Estimate		
	Low	Best	High
Overburden			
Concentration (ppb)	26,300 (26,350)*	35,055 (35,055)*	65,135 (65,100)*
Groundwater Flux (lb/day)	32,000 (32,000)*	193,000 (190,000)*	386,500 (380,000)*
Loadings (lb/day)	7 (7)*	57 (57)*	210 (209)*

* NOTE: Gradient/Geotrans Data in parentheses

4.4 OCCIDENTAL CHEMICAL, 102nd STREET (USGS SITES #40,56)

The detailed calculations performed by Monenco provided in Appendix E agree with those computed by Gradient Corp. and Geotrans Inc. within (+/-) 1 lb/day. The data are relatively recent (1986), and include a large number of wells (80). Unfortunately, only TOX and TOC values were used, since an entire suite of analyses was not available. A comparison between the 1985 comprehensive data on some wells and the 1986 data was made by Gradient Corp. and Geotrans Inc. but may not be valid because of two major problems identified below:

1) The two data sets were collected at two different times (even in different years) and were not necessarily collected in the same manner. These facts make it unrealistic to compare the resultant values.

2) The TOX/TOC equation does not in any way account for inorganic contaminants. A comparison, therefore, between the summation of organics and inorganics in the 1985 data and the TOX/TOC data from the 1986 data is invalid. The error inherent in this calculation is not determinable, since the concentration of inorganic components at the site boundary was not provided.

The presence of NAPL at this site is mentioned in the report but until the extent of the plume has been defined, it is impossible to estimate the contaminant loading of the plume on the Niagara River. Overall, the data for this site are fairly comprehensive. By analyzing for more parameters (particularly inorganics) and defining the NAPL plume, a reasonably confident loadings calculation could be made. A summary of the loadings calculation is provided in Table 4-2.

Table 4-2 Summary of Monenco's Contaminant Loading Calculations for Occidental Chemical's 102^{nd} Street Site

Parameter	Estimate		
	Low	Best	High
Overburden			
Concentration (ppb)	106,200 (106,000)*	145,479 (145,000)*	145,479 (145,000)*
Groundwater Flux (lb/day)	41,238 (40,056)*	126,022 (125,175)*	156,479 (150,210)*
Bedrock			
Concentration (ppb)	3,156 (3,200)*	4,323 (4,400)*	4,323 (4,400)*
Groundwater Flux (lb/day)	2,177 (2,170)*	22,167 (22,532)*	738,744 (751,050)*
Total Loadings (lb/day)	4 (4)*	18 (18)*	26 (25)*

* NOTE: Gradient/Geotrans data in parentheses.

4.5 OCCIDENTAL CHEMICAL, S-AREA (USGS SITE #41a)

The calculations performed by Gradient Corp. and Geotrans Inc. appear to be correct, based upon a detailed review (see Appendix E). Differences in the loadings, as calculated by Monenco are in the order of (+/-) 1 lb/day. The data for this site are out-of-date (some as early as 1980) and spread over a period of eight years. As well, the TOX/TOC formula appears to be a poor indicator of overall contamination at this site, since the formula overestimates the contaminant concentration by a factor of 10 compared to the sum of the individual analyses (as mentioned in the Gradient/Geotrans report). A variance of 0.5 to 1 order-of-magnitude difference exists between the contaminant concentration indicated by the formula and the summation of the individual contaminant concentrations.

The overall certainty of the loading estimate is much lower for this site than the Hyde Park site or 102nd Street Landfill due to the age and lack of completeness in the analytical data. Future work performed on this site should include the installation of more monitoring wells, and a larger number of parameters in the analysis list. A summary of the loadings calculation is provided in Table 4-3.

Table 4-3 Summary of Monenco's Contaminant Loading Calculations for Occidental Chemical's S-Area Site

Parameter	Estimate		
	Low	Best	High
Overburden			
Concentration (ppb)	148,000 (148,000)*	219,732 (220,000)*	219,732 (220,000)*
Groundwater Flux (lb/day)	14,701 (14,187)*	44,759 (43,394)*	75,105 (76,659)*
Bedrock			
Concentration (ppb)	3,205 (3,202)*	3,205 (3,202)*	9,200 (9,000)*
Groundwater Flux (lb/day)	786,563 (809,465)*	1,310,938 (1,335,200)*	2,097,500 (2,086,250)*
Total Loadings (lb/day)	5 (4.8)*	14 (14)*	36 (35)*

* NOTE: Gradient/Geotrans data in parentheses.

4.6 NECCO PARK AND CECOS (USGS SITE #14, 78a, 78b)

The data for this site are recent (1985 to 1987) and include a reasonably complete list of parameters. The calculations performed by Monenco agreed with those of Gradient Corp. and Geotrans Inc. within (+/-) 1 lb/day. The TOX/TOC formula was used for the Necco Park wells, because only 22 parameters were measured. According to Gradient and Geotrans, this equation overestimated the total contaminant loading by a factor of two (2), compared to the sum of the average chemical concentrations. The Gradient/ Geotrans report suggests that some parameters may have been omitted, but more likely, the equation is in error. The error is within the "order-of-magnitude" range suggested for this calculation. It should also be noted that the error results in a conservative estimate of the loadings.

NAPL has been noted on this site, but the plume has not been adequately defined. If the plume front has reached the Niagara River, a serious impact could be present that is not addressed by the report. It is more likely, however, that only the Aqueous Phase Liquid (APL) plume has reached the Niagara River. If the NAPL plume front has not reached the river, the loadings calculated could be reasonably accurate. The overall certainty of these calculations is medium to high, because the data are recent, and relatively complete. The estimate could be improved by adding more wells and sampling for the suite of U.S. EPA priority pollutants, in order to establish the relationship between the total organic contaminant concentration and the TOX/TOC analyses. A summary of the loadings calculations is provided in Table 4-4 below.

Table 4-4 Summary of Monenco's Contaminant Loading Calculations for the Necco Park and CECOS Sites

Parameter	Estimate		
	Low	Best	High
Upper Bedrock			
Concentration (ppb)	74,478 (74,000)*	146,286 (146,000)*	146,286 (146,000)*
Groundwater Flux (lb/day)	73,642 (73,436)*	368,208 (367,180)*	1,841,041 (1,835,900)*
Lower Bedrock			
Concentration (ppb)	14,274 (14,000)*	46,143 (45,000)*	46,143 (45,000)*
Groundwater Flux (lb/day)	44,690 (44,982)*	223,448 (224,910)*	1,117,238 (1,124,550)*
Total Loadings (lb/day)	6 (6)*	66 (65)*	320 (320)*

* NOTE: Gradient/Geotrans data in parentheses.

4.7 NIAGARA COUNTY REFUSE DISPOSAL (USGS SITE #81)

The recalculations for this site agree with the Gradient/Geotrans figures by (+/-) 1 lb/day, except the "high" estimate, which is 3 lb/day greater than the value calculated by Gradient Corp. and Geotrans Inc.. The overall confidence in the estimates, however, is very low compared to the other five sites in the detailed review. The data are relatively recent (1985-1987), but not comprehensive, as indicated below:

- No site specific hydrogeological properties were given
- No data were available for the bedrock
- The concentrations used for the best estimates were derived

from wells within the disposal area, and are likely overestimates of the contamination at the site boundary

- Ignoring attenuation could lead to serious overestimation of contaminant loadings, since the soils under the site consist of clays and silts

Hydraulic connection to the bedrock is discussed, but no data are presented with regard to bedrock contaminants or flow rates. If there is no attenuation at this site, the bedrock could be seriously contaminated and contaminant loadings could be much higher than estimated. The lower contaminant concentrations in the ditches and the boundary wells suggest that attenuation is significant at this site. Therefore, the calculated loadings are probably severe overestimates of the true loadings.

The bedrock under the site has not been examined thoroughly, and little, if anything is known about the bedrock flow conditions. The Camillus shale in most areas exhibits very low vertical permeability, and higher horizontal permeability. If the bedrock has a fractured zone, migration rates may be much higher.

Future studies are urgently needed at this landfill. With estimated loadings of 88 lb/day, this property has one of the highest loadings of any of the sites studied. The wastes disposed at this site could result in environmental damage if released from the landfill. The accuracy of the data, however, is questionable. Even Gradient Corp. and Geotrans Inc. rated the confidence level as "low". It is quite possible, given the limited data in the Gradient/Geotrans report, that this site is not a serious source of contaminants. A summary of the loading calculations is provided in Table 4-5 below.

Table 4-5 Summary of Monenco's Contaminant Loading Calculations for the Niagara County Refuse Disposal Site

Parameter	Estimate		
	Low	Best	High
Overburden			
Concentration (ppb)	9,000 (9,000)*	310,000 (310,000)*	310,000 (310,000)*
Groundwater Flux (lb/day)	93,638 (91,795)*	280,915 (283,730)*	461,949 (458,975)*
Loadings (lb/day)	0.8 (0.83)*	87 (88)*	143 (140)*

* NOTE: Gradient/Geotrans data in parentheses.

PART 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The methodology used by Gradient Corp. and Geotrans Inc. to assess the contaminant loadings is, as described in their report, an "order-of magnitude" calculation, with possible errors of (+/-) 2 to 3 orders-of-magnitude. Based upon Monenco's evaluation of the methodology and detailed calculations, the following conclusions may be made:

- Many data gaps are present, due to problems of confidentiality, inconsistencies in field and laboratory methods, and lack of current data due to studies that were not complete as of the publication date of the Gradient/Geotrans report

- The use of an arbitrary three (3) mile limit to determine the sites to estimate contaminant loadings to the Niagara River may have eliminated sites of concern

- The use of a generalized TOX/TOC formula to estimate contaminant concentrations is questionable because of the high degree of variability of the chlorine to carbon ratio in organic contaminants

- Data manipulation using other parameters, such as TVO, TVHO, HOS, and VHOS may not be comparable to that with TOX and TOC analyses

- The TOX/TOC ratio exhibits a great degree of variability; therefore, assuming a value for TOC based on a TOX analysis could cause serious errors

- There is no basis for assuming that 2/3 of the non-halogenated TOC is natural

- The most significant contaminants, iron and aluminum, which comprise 98% of the measured contaminant loading in the Niagara River, were not addressed by the report

- Trace metals, accounting for 2% of the measured loadings, were addressed in the report; the main emphasis, however, was on organics, which comprised less than .01% of the contaminant loading

- Attenuation and time lag are not covered in detail by the report; arbitrary boundaries were used to determine attenuation and the time lag factor was ignored; the advantage of this approach is that it provides a worst-case scenario and will likely overestimate the contamination

5.2 RECOMMENDATIONS

Based upon the conclusions noted previously, the methodology described in the Gradient/Geotrans report could be improved in the following ways.

- The Gradient/Geotrans report should be updated

- New data collected since the report was issued should be included

- Sampling and analysis protocols for all sites should be uniform and established by one authority, such as the US EPA; these protocols should address quality assurance (trip blanks, duplicate samples, spiked samples), as well as specifying desired detection limits and parameters for analysis

- With proper sampling protocols established, statistical methods could be utilized to support the accuracy of the estimated contaminant concentrations

- All of the sites should be scanned for all organic and inorganic parameters to determine an accurate relationship between TOX/TOC formula and the summantion of the individual compounds

- Individual chemical analyses should be used for all of the sites, in place of indicator parameters such as TOX and TOC; this would make it unnecessary to use the TOX/TOC equation, and could incorporate non-organic contaminants

- Standardized flow models should be used to compute the flow rates instead of analytical methods or in-house models; the models used should be identified in each case

- A sliding scale could have been used to account for attenuation which could eliminate some of the potential bias from the choosing of arbitrary zones

- A new study involving the installation of seepage monitors should be initiated along the Niagara River Gorge; although this would not indicate which companies are responsible for the pollution, it could allow direct measurement of contaminant flux into the river without the need for the many assumptions required for individual sites; and would identify the most severe areas to be investigated in the future (but would not identify plumes which have not yet reached the Niagara River)

- Use of the Niagara River drainage boundary for site-selection criteria rather than an arbitrary three (3) mile limit

- Implementation of field investigations at the sites noted as lacking sufficient data; in particular, the field studies should initially be directed towards the three sites designated by Koszalka et al. (1984) as having "major potential" for migration; this includes USGS sites 105 (Allied Chemical, Tonawanda), 138 (McNaughton/Brooks Inc.) and 203 (Squaw Island)

- Implementation of field investigations at the four (4) sites designated as having "limited evidence" of contaminant migration should also be investigated; this list includes USGS sites 62 (Stauffer Chemical, North Love Canal), 78 (Lynch Park), 83 (Buffalo Avenue) and 115 (Ashland Petroleum)

- Implementation of revised desktop studies of the 64 sites listed by the USGS which may or may not be releasing contaminant discharges into the Niagara River; these sites currently lack proper groundwater data and should be checked with field investigations, if required

Respectively Submitted

MONENCO CONSULTANTS LIMITED

D.C. Ford, Hydrogeologist

R.C. Ostry, P. Eng., Project Manager

PART 6 - REFERENCES

Feenstra, S., 1987. *Screening/Indicator Parameters For Organic Contaminants in Groundwater.* Water Pollution Resources Journal of Canada, Volume 22, Number 1, 1987.

Koszalka, E.J., J.E. Pascal, Jr., T.S. Miller, and P.B. Duran, 1985. *Preliminary Evaluation of Chemical Migration to Groundwater and the Niagara River from Selected Waste-Disposal Sites.* Prepared by the U.S. Geological Survey in cooperation with the New York State Department of Environmental Conservation for the U.S. Environmental Protection Agency, Great Lakes National Program Office. EPA-905/4-85-001.

Myers, J., R. Bryan, 1989. *Geostatistical Analysis of Hazardous Waste. A Short Course For the Environmental Professional.* Presented by Geostatistical Specialists, ESTOX Inc., Golden, Colorado.

NRTMP (Niagara River Toxics Management Plan) River Monitoring Committee, 1987. *River Monitoring Data for the Period April 1986 to March, 1986.* Joint Report of the Niagara River Data Interpretation Group.

Shifirin, N., Gradient Corp. Personal Communication, October 4, 1989.

Spiegel, M.R., 1968. *Mathematical Handbook of Formulas and Tables.* McGraw-Hill Book Company, Toronto, Ontario.

APPENDIX A

SUMMARY OF CHEMICAL DATA FOR ALL SITES EXAMINED BY GRADIENT AND GEOTRANS

The following table provides a summary of the chemical data used by Gradient Corp. to calculate the contaminant concentrations for all of the 33 sites that they investigated. Also provided is a comparison between the formula used by Gradient Corp. and the alternative formula suggested by Monenco. The explanations of the equations and their derivations are provided in section 3.2.2.

Site	Sum of Avg. Conc. (ppb)	TOX (ppb)	TOC (ppb)	Conc. from Formula (Gradient) (ppb)	Conc. from Formula (MCL) (ppb)	Comments
SKW Alloys	17,000	n/a	41,000			Overburden
	5,000	n/a	36,000			Bedrock, western border
	5,300	n/a	26,000			Bedrock, eastern border
Bell Aerospace	4,200	2,100	120,000	53,460	138,720	Overburden
Textron	2,300	170	125,000	50,442	138,044	Bedrock, southern border
	500,000	22,000	260,000	161,200	356,400	Bedrock, northern border
Necco Park/						All Bedrock Wells
CECOS	50,583	29,000	102,200	116,280	205,220	1st Qtr. 1987 (southern)
	98,371	9,014	454,000	205,036	528,245	5 CECOS wells (southern)
	n/a	19,006	278,000	160,616	366,619	Avg. of CECOS & NP wells
	14,274	14,314	19,810	45,140	67,596	1st Qtr. 1987 (Western)
	168,400	38,100	1,250,700	599,340	1,497,690	Necco Park, 36 parameters
	156,500	38,100	1,250,700	599,340	1,497,690	Necco Park, 22 parameters
Dupont,	930	110	6,300	2,806	7,282	Overburden, Zone 1
Buffalo Avenue	9,000	1,870	4,300	6,582	10,714	Overburden, Zone 2
	130,000	21,000	8,800	58,120	76,880	Overburden, Zone 3
	380,000	49,000	98,000	166,600	264,600	Overburden, Zone 4
	290	50	5,000	2,130	5,660	Overburden, Zone 5
	210	55	3,800	1,663	4,356	Bedrock, Layer 1E
	7,000	810	6,600	4,746	9,852	Bedrock, Layer 1W
	700	2,000	4,600	7,040	11,460	Bedrock, Layer 2E
	27,000	81,000	6,300	213,120	266,130	Bedrock, Layer 2W
	9,600	3,400	2,700	9,920	13,850	Bedrock, Layer 3E
	3,100	1,500	3,300	5,220	8,430	Bedrock, Layer 3W

Site	Sum of Avg. Conc. (ppb)	TOX (ppb)	TOC (ppb)	Conc. from Formula (Gradient) (ppb)	Conc. from Formula (MCL) (ppb)	Comments
Great Lakes Carbon	220	n/a	n/a			Overburden
Occidental, Durez	10,784	n/a	n/a			Overburden, 1980-83
	3,944	n/a	26,000			Overburden, 1 well, 1983
	10	n/a	n/a			Bedrock, 1985
	14	n/a	n/a			Bedrock, 1982
Occidental, Love Canal	n/a	n/a	n/a			
Occidental, Hyde Park	35,055	8,820	8,770	26,440	37,871	Gorge face seeps
102nd Street Griffon Park Belden Site						Overburden Wells
	74,800	9,800	81,000	57,880	120,460	102nd, RI wells
		14,000	17,450	43,380	63,995	102nd, south boundary
		350	220,000	88,910	243,120	Griffon, river boundary
		160	145,000	58,416	160,012	Belden, 1 well
						Bedrock Wells
		260	6,200	3,156	7,652	102nd, south boundary
		350	5,000	2,910	6,620	Griffon, 1 well
Occidental, S-Area						Overburden
	148,000	66,250	855,000	514,250	1,152,500	southern boundary
	n/a	44,820	258,000	219,732	427,224	southern boundary + offsite
						Bedrock
	280	925	2,000		5,160	northerly settlement wells

Site	Sum of Avg. Conc. (ppb)	TOX (ppb)	TOC (ppb)	Conc. from Formula (Gradient) (ppb)	Conc. from Formula (MCL) (ppb)	Comments
Occidental,						Overburden
Buffalo Avenue	27	3,360	11,000	13,136	22,852	1 well
	79,820	62	14,000	5,761	15,598	1 well
	1,949	5,100	90,000	49,260	115,320	1 well
	18,964	24,000	66,000	88,800	149,400	1 well
	n/a	11,480	70,110	57,892	113,857	southern boundary
	n/a	13,580	69,600	63,148	120,016	All wells
						Bedrock
	n/a	11,400	54,000	51,240	95,880	Northern boundary
	n/a	30,860	65,250	106,336	170,527	Western boundary
Olin,	1,100	222	222	666	955	Overburden
Buffalo Avenue	4,800	2,130	2,130	6,390	9,159	Bedrock
NOTE: TOX and TOC not analyzed. Instead, a Halogenated Organic Scan (HOS) and a Volatile Halogenated Organic Scan (VHOS) were performed. TOX was assumed to equal HOS + VHOS, and TOC was assumed to equal TOX						
Reichhold-	660,000	n/a	n/a			Overburden
Varcum	140,000	n/a	n/a			Bedrock, Layer 1
	34,000	n/a	n/a			Bedrock, Layer 2
	29,000	n/a	n/a			Bedrock, Layer 3
Frontier	110,000	n/a	n/a			Overburden, S.E.
Chemicals	70,000	n/a	n/a			Entire site
Gratwick,	4,420	n/a	n/a			Overburden, 1983
Riverside Park	1,120	n/a	n/a			Overburden, 1982
	n/a	205,000	130	533,052	656,143	Overburden, 1979-1980

Site	Sum of Avg. Conc. (ppb)	TOX (ppb)	TOC (ppb)	Conc. from Formula (Gradient) (ppb)	Conc. from Formula (MCL) (ppb)	Comments
Niagara County	76	n/a	n/a			Overburden, USGS
Refuse Disposal	9,000	n/a	n/a			Overburden, NUS wells
	310,000	n/a	n/a			Overburden, EA wells
Notes: NUS: NUS Corporation EA: EA Science and Technology						
Allied Chemical	638	n/a	n/a			Overburden, 1985
NOTE: Inorganics only						
						Overburden Wells
Tonawanda Coke	430	1	n/a			western boundary
	1,900	9	n/a			all wells
	610	2	n/a			all wells but 1
						Overburden Wells
Bethlehem Steel	390	25	10,500			Ammonia lime sludge area
	1,100	33	12,000			Tar sludge area
	270	37	14,000			Spent pickle liquor area
	790	n/a	24,000			Entire site
						Bedrock wells
	130	n/a	13,500			Entire site
						Overburden Wells
Buffalo Color	32,000	63	54,000	21,764	59,602	weathering area
Corp.	18,000	740	450,000	181,924	497,368	sludge lagoon area
	13,000	300	180,000	72,780	198,960	overall site

Site	Sum of Avg. Conc. (ppb)	TOX (ppb)	TOC (ppb)	Conc. from Formula (Gradient) (ppb)	Conc. from Formula (MCL) (ppb)	Comments
Columbus McKinnon	n/a	1,618	1,618	4,854	6,957	Overburden, 8/15/83 data
	210	1,160	1,160	3,480	4,988	Overburden, 10/20/83 data
	320	n/a	n/a			Overburden, 8/27/84 data

NOTE: TOX assumed to be equal the sum of Total Halogenated Organics (THO) and Total Volatile Halogenated Organics.
TOC assumed to be equal to TOX.

Site	Sum of Avg. Conc. (ppb)	TOX (ppb)	TOC (ppb)	Conc. from Formula (Gradient) (ppb)	Conc. from Formula (MCL) (ppb)	Comments
Dunlop Tire & Rubber	6	n/a	n/a			Overburden, 1983
	295	n/a	n/a			Overburden, 1986-87
	4E-01	n/a	n/a			Bedrock, 1983
	82	n/a	n/a			Bedrock, 1986-87
INS Equipment	5,000	10	5,000	2,025	5,531	Overburden, W. border
	5,300	10	40,000	16,026	44,032	Overburden, entire site
Mobil Oil	65	14	16,700	6,716	18,414	Overburden
Alltift Realty	580	n/a	n/a			Overburden, S. boundary
	1,400	n/a	n/a			Overburden, W. boundary
Huntley Power Station	460	n/a	n/a			Overburden, W. boundary
	410	n/a	n/a			Overburden, entire site
Tonawanda Landfill	95	n/a	n/a			Overburden, 1 well

Site	Sum of Avg. Conc. (ppb)	TOX (ppb)	TOC (ppb)	Conc. from Formula (Gradient) (ppb)	Conc. from Formula (MCL) (ppb)	Comments
Times Beach						Overburden Wells
	540	n/a	n/a			Western boundary
	1,300	n/a	n/a			Western boundary
	830	n/a	n/a			Entire site
	1,300	n/a	n/a			Entire site
	310,000	n/a	n/a			Entire site
Charles Gibson	7,800	n/a	n/a			Overburden, N.E. boundary
	9,300	n/a	n/a			Overburden, entire site
Solvent Chemical	8,600	44,500	n/a			Overburden, N.E. boundary
	11,000	42,000	n/a			Overburden, N.E. boundary
Small Boat Harbour	20,000	n/a	n/a			Overburden, 1983
	29,000	n/a	n/a			Overburden, 1986
Buffalo Harbour	26,000	n/a	n/a			Overburden, 1985
Stauffer Chemical	11,380	n/a	n/a			Upper Loackport
	42,420	n/a	n/a			Lower Lockport
	102,140	n/a	n/a			Lockport/Rochester Interface
	93,420	n/a	n/a			Rochester
	164,100	n/a	n/a			Below Rochester

APPENDIX B

DESCRIPTIONS OF SELECTED SITES DELETED BY GRADIENT CORP. AND GEOTRANS INC.

The following sites were described by Koszalka et al. as having "major" evidence of contaminant migration, but were dismissed by Gradient/Geotrans due to lack of data:

Site 105: Allied Chemical, Tonawanda Site

operation: 1950-1980

waste: Unknown quantity of scrap chlorinated & non-chlorinated polyethylene and spent catalyst

chemical data: Indicates migration of chromium, nickel, and lead higher than background
21 organic priority pollutants detected
11 non-priority pollutants detected

soils: Clay over Camillus Shale

groundwater: Not encountered

Comments: Could be a major contributor, but not enough data to assign values to contaminant concentrations and flow rates.

Site #138: McNaughton/Brooks Inc.

operation: 1960's -1966 (start-up date not precisely known)

waste: 600 gallons of solvents, including Xylol, toluol and paint sludge

chemical data: High concentrations of synthetic organic compounds in soils
22 organic priority pollutants
21 non-priority pollutants
"Some unknown hydrocarbons"

soils: Rubble pile with clay layer below

groundwater: Unknown

comments: This site could be a major contributor of organics, but the occurrence of horizontal movement has not been determined. Note the relatively low volume, but toxic nature of the waste.

Site #203: Squaw Island

operation: 1954-1970

waste: 300,000-400,000 tons/year of foundry sand, incinerator residue, street sweepings, forest debris, general refuse

NOTE: The waste was excavated in the 1970's and disposed of in another landfill.

chemical data: 17 organic priority pollutants
25 organic non-priority pollutants
"Some unknown hydrocarbons"

soils: Unknown

groundwater: Unknown

comments: Due to the high permeability of the foundry sand and incinerator residue, groundwater movement is probably rapid. As well, the disposal site is an island, and the refuse was used as fill to make the island larger, Therefore, the refuse is (or was) in close proximity to the Niagara River. The unanswered questions are whether or not all of the material was removed, and whether or not all of the contaminated soils were removed. If all of the refuse and contaminated soils have been removed, this site should not be causing any contaminant discharges into the Niagara River at the present time.

The following sites were described by Koszalka et al., 1985 as having "limited potential" for contaminant migration, or hydraulic connection to the Niagara River, but were dismissed by Gradient Corp. and Geotrans Inc. because of insufficient data:

Site #62: Stauffer Chemical, North Love Canal

operation: 1930-1952

waste: 50,000 yd^3 of waste asbestos, cell parts, reactor linings, scrap sulphur, metallic wastes, and possibly flux.

chemical data: High concentrations of "some chemicals" in off-site soil and water

soils: 1.5-17 feet of clayey silt (till?) over Lockport Dolomite Clay cover

comments: A subdivision is now over the site. Soils are probably relatively impermeable, but thin in some places. Therefore, migration into the Lockport Dolomite cannot be ruled out. If migration has occurred, this site could contribute significant contaminant discharges into the Niagara River.

Site #78: Lynch Park

operation: Unknown

waste: Clean fill and rubble from an abrasives plant.

chemical data: High copper concentrations in some soil samples

soils: Unknown

groundwater: Unknown

comments: This site is probably a minor contributor of contaminants into the Niagara River, but as of yet, very little is known about the site.

Site #83: Buffalo Avenue

operation: 1930-1950

waste: Unknown amount of non-combustibles and incinerator ash

chemical data: 12 priority pollutants detected, some above 1500 ppb
10 organic, no-priority pollutants detected

soils: Unknown

groundwater: Unknown

comments: Organics found, but no proof of migration

Site #115: Ashland Petroleum

operation: 1944-1946

waste: 8000 tons of uranium ore tailings containing 0.54% uranium to a depth of 2 feet.

chemical data: Indicates offsite migration by surface run-off low-level radioactivity (below Nuclear Regulatory Commission Standards), heavy metals detected in ditches

soils: Clay over Camillus Shale

groundwater: No groundwater data

comments: Could be a minor to moderate contributor, but no data available to properly assess the site.

APPENDIX C

PRIORITY RANKING OF SELECTED U.S. HAZARDOUS WASTE SITES

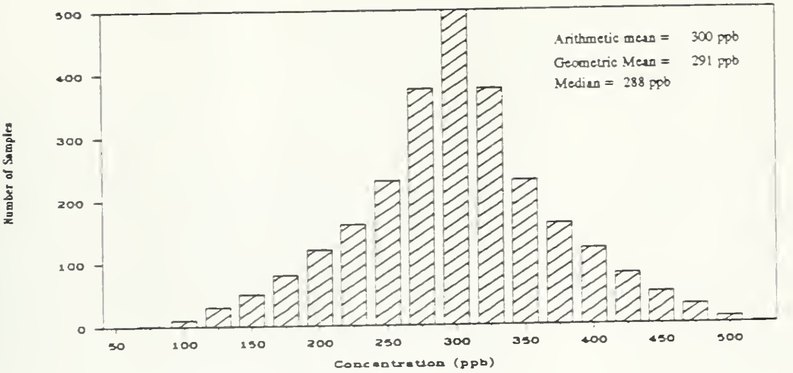
Site Name	USGS Site Numbers	Loadings		
		Best (ppb)	Low (ppb)	High (ppb)
Sites Included in the Gradient/ Geotrans Study				
Occidental Buffalo Ave.	41b-49	340.00	80.00	1100.00
Niagara County Refuse Disposal	81	88.00	0.83	140.00
Necco Park/CECOS	78a-b,14	65.00	6.00	320.00
Occidental Hyde Park	39	57.00	7.00	210.00
102nd Street	85,94,40,56	26.00	6.40	40.00
Bell Aerospace Textron	5	19.00	0.65	74.00
Reichhold-Varcum	66	15.00	1.50	150.00
S-Area	41a	14.00	4.80	35.00
Stauffer, PASNY	255	12.00	1.70	690.00
Solvent Chemical	251	9.30	0.93	670.00
SKW Alloys	1	8.60	1.40	220.00
Olin Buffalo Ave. Plant	58;59,248	7.10	0.14	460.00
Dupont Buffalo Ave.	15-19,250	6.60	1.30	59.00
Buffalo Harbour Containment Site	254	6.10	2.00	11.00
Buffalo Colour Corporation	120-122	4.40	0.20	12.00
Bethlehem Steel	118	3.00	0.59	130.00
INS Equipment Corporation	136	2.70	0.21	7.40
Frontier Chemical Pendleton	67	2.60	0.51	6.90
Occidental Chemical, Durez	24-37	2.00	0.40	140.00
Small Boat Harbour Site	253	1.80	0.27	6.10
Gratwick Riverside	68	1.30	0.08	52.00
Mobil Oil Corporation	141	1.30	0.00	6.90
Alltift Realty	162	0.17	0.05	0.68
Charles Gibson	242	0.16	0.04	0.46
Great Lakes Carbon	22	0.13	0.03	0.66
Huntley Power Station	182	0.11	0.04	1.20
Times Beach Containment Site	241	0.09	0.02	22.00
Tonawanda Coke	108-110	0.06	0.02	0.46
Allied Chemical	107	0.02	0.00	0.07
City of Tonawanda Landfill	207	0.01	0.00	0.01
Dunlop Tire and Rubber	125-127	0.00	0.00	0.42
Columbus-McKinnon	123	0.00	0.00	0.06
Love Canal	38	0.00	0.00	0.00

Site Name	USGS Site Numbers	Loadings		
		Best (ppb)	Low (ppb)	High (ppb)
Sites Deleted From the Gradient/ Geotrans Study				
Squaw Island	203	n/a	n/a	n/a
Allied Chemical, Tonawanda	105	n/a	n/a	n/a
McNaughton/Brooks Inc.	138	n/a	n/a	n/a
Stauffer Chemical	62	n/a	n/a	n/a
Lynch Park	78	n/a	n/a	n/a
Buffalo Ave.	83	n/a	n/a	n/a
Asland Petroleum	115	n/a	n/a	n/a
Total		693.55	117.12	4566.32

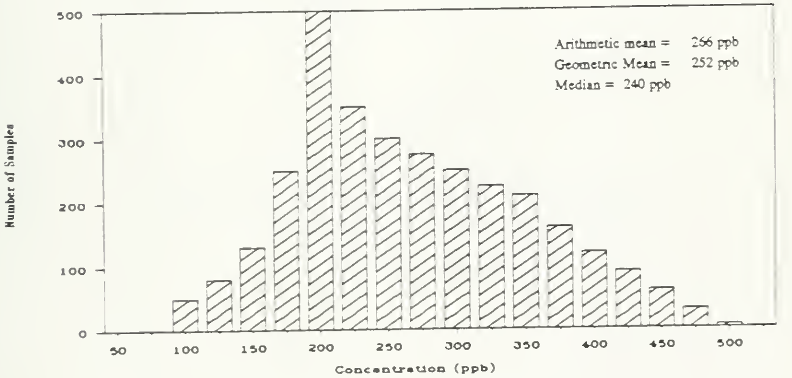
APPENDIX D

STATISTICAL DISTRIBUTIONS WITH CALCULATIONS OF SELECTED STATISTICS

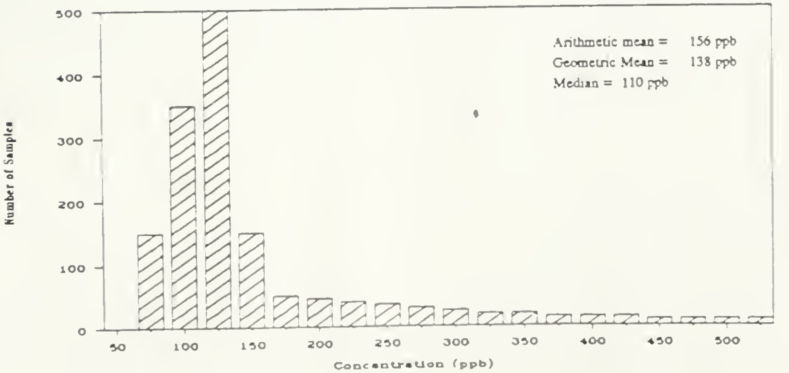
Normal Distribution



Skewed Normal Distribution



Log-Normal Distribution



APPENDIX E

RECALCULATED LOADINGS OF THE 5 SITES ON THE NATIONAL PRIORITY LIST SITES AND NECCO PARK/CECOS

APPENDIX E-1
CALCULATION VERIFICATION
OCCIDENTAL CHEMICAL, LOVE CANAL
USGS SITE #38

Contaminant Loading was not calculated for this site, since remediation procedures have isolated the site from the Niagara River.

APPENDIX E-2
CALCULATION VERIFICATION
OCCIDENTAL CHEMICAL, HYDE PARK
USGS SITE #39

DATA: (1984 Data, Overburden not considered)

Bedrock	Sum of all Components (ppb)	TOX (ppb)	TOC (ppb)
Gorge Face Seeps 1-4, 40 compounds analyzed	35,055	8,770	8,820

Calculations:

Best Estimate of Bedrock Concentration

The Sum of all compounds measured at the gorge face was used as the best estimate.

$C = 35{,}055$ ppb

Low Estimate of the Bedrock Concentration

Using the TOX and TOC data yields:

$C = 2.6\ TOX + 0.4\ TOC = 2.6 * 8{,}770 + 0.4 * 8{,}820$
$C = 26{,}330$ ppb

High Estimate of the Bedrock Concentration

Using the best estimate of the concentration, and adding compounds detected on site, but not analysed for at the seeps yields:

$C = 35{,}055 + 30{,}080$
$C = 65135$ ppb

FLOW CALCULATIONS:

Best Estimate

Estimate	(gal/day)	(lb/day)	Comments
Best	193,248	1,612,655	(model)
Low	32,256	269,176	(model + recharge at 1" /yr)
High	386,496	3,225,309	(model + recharge at 12"/yr)

Conversions Used: 1 gal = 8.345 lb
1 day = 1440 minutes

LOADING CALCULATIONS

Best Estimate:

L = C * Flow
L = 3.5 x 10-5 * 1,612,655 lb/day
L = 57 lb/day

Low Estimate:

L = C * Flow
L = 2.6 x 10-5 * 420,588 lb/day
L = 7 lb/day

High Estimate:

L = C * Flow
L = 6.5 x 10-5 * 3,436,805 lb/day
L = 210 lb/day

Note: These estimates agree with those of Gradient/Geotrans by (+/-) 1 lb/day.

APPENDIX E-3
CALCULATION VERIFICATION
FOR OCCIDENTAL CHEMICAL, 102nd STREET SITE
USGS SITES #40,56

DATA: (1986)

Zone	Sum of All Componments (ppb)	TOX (Necco) (ppb)	TOC (ppb)
Overburden	79300	14,000	174,500
Bedrock	N/A	260	6,200

Calculations:

Best Estimate of the Contaminant Concentration

Using the TOX and TOC data yields:

Overburden

$$C = 2.6\ TOX + 0.4\ TOC = 2.6 * 14{,}000 + 0.4 * 174{,}500$$
$$C = 106{,}200 \text{ ppb}$$

Bedrock

$$C = 2.6\ TOX + 0.4\ TOC = 2.6 * 260 + 0.4 * 6{,}200$$
$$C = 3{,}156 \text{ ppb}$$

These data were then corrected to correlate with the summation of all parameters that were analysed. The TOX/TOC equation could represent an underestimation of the total concentration by a factor of 73%, based on data from some of the well son the site.

This correction factor results in the following values:

Overburden

$$C = 106{,}200/0.73$$
$$C = 145{,}479 \text{ ppb}$$

Bedrock

$$C = 3{,}156/0.73$$
$$C = 4{,}323 \text{ ppb}$$

Low Estimate, Lower Bedrock Concentration:

Using the TOX and TOC data yields:

Overburden

$$C = 2.6\ \mathrm{TOX} + 0.4\ \mathrm{TOC} = 2.6 * 14{,}000 + 0.4 * 174{,}500$$
$$C = 106{,}200\ \mathrm{ppb}$$

Bedrock

$$C = 2.6\ \mathrm{TOX} + 0.4\ \mathrm{TOC} = 2.6 * 260 + 0.4 * 6{,}200$$
$$C = 3{,}156\ \mathrm{ppb}$$

High Estimate of the Bedrock Concentration

There is no basis for this calculation, therefore the best estimate concentration values will be used.

FLOW CALCULATIONS:

Bedrock

Layer	Hydraulic Conductivity k (ft/day)	Hydraulic Gradient (i)	Saturated Thickness (ft)	Unit Length (ft)	Flux Q (ft^3/day)	Flux Q (lb/day)
High	57	0.0025	60	1385	11,842	738,774
Best	6	0.0010	45	1385	355	22,163
Low	3	0.0003	30	1385	35	2,177

Note: Conversions used - 1 ft^3 = 7.476 US gallons
- 1 gal = 8.3450 lb (water)

Overburden

The overburden flux was determined by recharge rates

Recharge Parameters

Estimated Precipitation Rate	37 in/yr
Potential Evapotranspiration Rate	24-37 in/yr
Run-off	little
Groundwater Inflow	little
Area of Recharge to Landfill	961,350 ft^2

Recharge Estimates

High	15 in/yr	3,292 ft^3/day
Medium	9 in/yr	1,975 ft^3/day
Low	3 in/yr	658 ft^3/day

Estimated Flow Rates

Unit	Flow Direction	% of Total Recharge	Estimated Flux (ft^3/day) For Each Recharge Rate		
			High	Best	Low
Q1 Waste	West	0.33	11	7	2
Q2 Waste	South	1.18	39	23	8
Q3 Waste	Est	0.27	9	5	2
Q4 Alluvium	West	1.45	48	29	10
Q5 Alluvium	South	63.44	1300	1300	420
Q6 Alluvium	East	2.57	85	51	17
Q7 Clay/Till	Downward	1.75	58	35	12
Q9 Sewer Inflow	South	29	960	570	190
Total		99.99	2510	2020	661

Unit	Estimated Flux (gal/day) For Each Recharge Rate			Estimated Flux (lb/day) For Each Recharge Rate		
	High	Best	Low	High	Best	Low
Q1 Waste	82	52	15	686	437	125
Q2 Waste	292	172	60	2,433	1,435	499
Q3 Waste	67	37	15	561	312	125
Q4 Alluvium	359	217	75	2,995	1,809	624
Q5 Alluvium	9,719	9,719	3,140	81,103	81,103	26,203
Q6 Alluvium	635	381	127	5,303	3,182	1,061
Q7 Clay/Till	434	262	90	3,618	2,184	749
Q9 Sewer Inflow	7,177	4,261	1,420	59,892	35,561	11,854
Total	18,765	15,102	4,942	156,592	126,022	41,238

Loading Calculations

Best Estimate:

L = C(Overburden) x Flow(Overburden + C(Bedrock x Flow(Bedrock)
L = (1.45x10-4 x 126,022) + (4.32x10-6 x 22,167)
L = 18 lb/day

Low Estimate:

L = C(Overburden) x Flow(Overburden + C(Bedrock x Flow(Bedrock)
L = (1.06x10-4 x 41,238) + (3.16x10-6 x 2,177)
L = 4 lb/day

High Estimate:

L = C(Overburden) x Flow(Overburden + C(Bedrock x Flow(Bedrock)
L = (1.45x10-4 x 156,479) + (4.32x10-6 x 738,744)
L = 26 lb/day

Note: These estimates agree with the Gradient/Geotrans figures by (+/-) 1 lb/day.

APPENDIX E-4
CALCULATION VERIFICATION
OCCIDENTAL CHEMICAL, S-AREA
USGS SITE #41a

DATA: (Overburden: 1980, 1984; Bedrock: 1987)

Zone	Sum of all Components (ppb)	TOX (ppb)	TOC (ppb)
Overburden: Boundary Wells	148,000	66,250	855,000
Overburden: Boundary + Offsite	-	44,820	258,000
Bedrock	280	925	2,000

Calculations:

Best Estimate

Using the TOX and TOC data (boundary and offsite wells) yields:

Overburden

C = 2.6 TOX + 0.4 TOC = 2.6 * 66,250 + 0.4 * 855,000
C = 219,732 ppb

Bedrock

C = 2.6 TOX + 0.4 TOC = 2.6 * 925 + 0.4 * 2,000
C = 3,205 ppb

Low Estimate

The low estimate of the contaminant concentration was derived using the sum of the priority pollutants

Overburden

C = 148,000 ppb

Bedrock

There is no basis in the data for this calculation

High Estimate

Overburden

There is no basis in the data for this calculation

Bedrock

The analyses are not available, but the report states that the TOX/TOC values indicate a contaminant concentration of 92000 ppb, using the standard formula. This value was diluted by a factor of 10 to represent a boundary condition.

therefore, C = 9200 ppb

FLOW CALCULATIONS:

Darcy's Law

Estimate	Hydraulic Cond. k (ft/day)	Hydraulic Gradient i	Saturated Thickness (ft)	Unit Length (ft)	Flux Q (ft^3/day)	Flux Q (lb/day)
Overburden						
Q1 High	13	0.0050	20	1200	1,560	67,516
Q1 Medium	6	0.004	20	1200	576	24,929
Q1 Low	0.3	0.003	20	1200	22	935
Q2 High	0.002	0.4000	Area=348,480 ft^2		279	12,066
Q2 Medium	0.0002	0.2	Area=348,480 ft^2		14	603
Q2 Low	0.00002	0.1	Area=348,480 ft^2		1	30
Total Overburden						
High					1,839	79,582
Medium					590	25,532
Low					22	965
Bedrock	ft`/day					
Q3 High	T=5600	0.0060		1000	33,600	2,097,500
Q3 Medium	T=3500	0.0060		1000	21,000	1,310,938
Q3 Low	T=2100	0.0060		1000	12,600	786,563

The overburden rates were determined by recharge rates

Recharge Parameters

Estimated Precipitation Rate:	37 in/yr
Potential Evapotranspiration Rate:	24-37 in/yr
Runoff:	Little
Groundwater Inflow:	Little (except into bedrock)
Area of Recharge to Landfill:	348,480

Recharge Estimates

High	15 in/yr	3292 ft^3/day
Medium	9 in/yr	1975 ft^3/day
Low	3 in/yr	658 ft^3/day

Estimated Flow Rates

Unit	Flow Direction	% of Total Recharge	Estimated Flows (ft^3/day) for each Recharge Rate		
			High	Best	Low
Q1 Waste	West	97.63	1200	700	230
Q2 Waste	South	2.37	28	17	5.5
Total		100	1228	717	235.5

Conversions Used: 1 ft^3 = 7.4806 gal(US)
1 gal(US) = 8.3450 lb

Unit	Estimated Flows (gal/day) for each Recharge Rate			Estimated Flows (lb/day) for each Recharge Rate		
	High	Best	Low	High	Best	Low
Q1 Waste	8,977	5,236	1,721	74,911	43,698	14,358
Q2 Waste	209	127	41	1,748	1,061	343
Total	9,186	5,364	1,762	76,659	44,759	14,701

LOADING CALCULATIONS

Best Estimate:

L = C(Overburden)*Flow(Overburden)+C(bedrock)*Flow(Bedrock)
L = (2.20x10-4 * 44,759 lb/day)+(3.21x10-6 * 1,310,938 lb/day)
L = 14 lb/day

Low Estimate:

L = C(Overburden)*Flow(Overburden)+C(bedrock)*Flow(Bedrock)
L = (1.48x10-4 * 14,701 lb/day)+(3.21x10-6 * 786,563 lb/day)
L = 5 lb/day

High Estimate:

L = C(Overburden)*Flow(Overburden)+C(bedrock)*Flow(Bedrock)
L = (2.20x10-4 * 76,659 lb/day)+(9.20x10-6 * 2,097,500 lb/day)
L = 36 lb/day

Note: These figures agree with the Gradient/Geotrans report by (+/-) 1 lb/day.

APPENDIX E-5
CALCULATION VERIFICATION FOR NECCO PARK AND CECOS USGS SITES #14, 78a, 78b

DATA: (1986, 1987) in ppb

Upper Bedrock (South Boundary)	Well	1st Qtr. 1987 (Necco) Organics	1985/1986 (CECOS) Organics	Contaminant Concentrations (ppb)		
				Barium	TOX	TOC
Necco Park	145C	69,868		191,000	46,000	140,000
	145D	19,979		1,000	11,000	94,000
	146C	14,713		1,000	10,000	20,000
	146D	139,753		1,000	74,000	180,000
	C83	8,604		1,000	4,000	76,000
Average		50,583		39,000	29,000	102,000
CECOS	1		517		5	12,000
	8		186,946		27,000	1,100,000
	42		59,196		12,000	1,090,000
	26		232,152		63	32,000
	83		13,047		6,000	36,000
Average		50,583	98,372			

Calculations:

Best Estimate of Upper Bedrock Concentration

Using the TOX and TOC data for the Necco Park site yields:

$$C = 2.6\ TOX + 0.4\ TOC = 2.6 * 29{,}000 + 0.4 * 102{,}000$$
$$C = 116{,}200 \text{ ppb}$$

Averaging the TOX/TOC value with the average of the sum of all organics from the CECOS site yields:

$$C = 107{,}286 \text{ ppb}$$

adding the barium concentration yields:

$$C = 107{,}285 + 39{,}000$$
$$C = 146{,}286 \text{ ppb}$$

Low Estimate of the Upper Bedrock Concentration

Using the average of the Organic parameters for both Necco Park and CECOS yields:

$$C = 98,372 + 50,583/2$$
$$C = 74,478 \text{ ppb}$$

DATA: (in ppb)

Lower Bedrock (W. Boundary)	Well	1st Qtr. 1987 Organics Necco	Barium	TOX	TOC
	136E	18,364	1,000	16,000	18,000
	136F	41,413	1,000	27,000	28,000
	136G	4,968	1,000	3,700	22,000
	136J	2,034	1,000	500	20,000
	143F	12,414	1,000	52,000	44,000
	143G	9,618	1,000	500	4,700
	143J	11,108		500	2,000
Average		14,274	1,000	14,314	19,814

Calculations:

Best Estimate, Lower Bedrock Concentration:

Using the TOX/TOC Formula yields:

$$C = 2.6 * TOX + 0.4 * TOC$$
$$C = 2.6 * 14,314 + 0.4 * 19,814$$
$$C = 45,143 \text{ ppb}$$

accounting for barium adds

$$C = 45,143 + 1000$$
$$C = 46,143 \text{ ppb}$$

Low Estimate, Lower Bedrock Concentration

Using the average of the 22 organic parameters for the Necco Park Wells

$$C = 14,274 \text{ ppb}$$

FLOW CALCULATIONS:

Best Estimate

Layer	Hyd. Cond. k (ft/sec)	Hyd. Gradient	Saturated Thickness (ft)	Length (ft)	Flux Q ft^3/sec	Flux Q (gal/day)	Flux Q (lb/day)
Bedrock #1	3.3E-04	4.6E-03	25	1800	6.8E-02	44,123	368,208
Bedrock #2	3.0E-04	2.8E-03	60	550	2.8E-02	17,905	149,418
Bedrock #3	1.5E-04	1.4E-03	60	1090	1.4E-02	8,871	74,030

Note: Conversions used - 1 ft^3 = 7.476 gal(US)
- 1 day = 86,400 seconds
- 1 gal = 8.3450 lb (water)

Low Estimates:

The low estimates were derived by dividing the best estimates by a factor of five (5), the assumed margin of error.

High Estimates:

The high estimates were dervived by multiplying the best estimates by a factor of five (5), the assumed margin of error.

The chart below provides the values of Q in gal/day and lb/day

Layer	Best (gal/day)	Best (lb/day)	Low (gal/day)	Low (lb/day)	High (gal/day)	High (lb/day)
Bedrock #1	44,123	368,208	8,825	73,642	220,616	1,841,042
Bedrock #2	17,905	149,418	3,581	29,884	89,525	747,089
Bedrock #3	8,871	74,030	1,774	14,806	44,356	370,149

LOADING CALCULATIONS

Best Estimate:

L = C(Upper) * Flow(Upper) + C(Lower) * Flow(Middle + Lowest)
L = (1.5x10-4 * 368,208 lb/day) + (4.6x10-5 * 223,448 lb/day)
L = 66 lb/day

Low Estimate:

L = C(Upper) * Flow(Upper) + C(Lower) * Flow(Middle + Lowest)
L = (7.4x10-5 * 73,642 lb/day) + (4.6x10-5 * 44,690 lb/day)
L = 6 lb/day

High Estimate:

L = C(Upper) * Flow(Upper) + C(Lower) * Flow(Middle + Lowest)
L = (1.5x10-4 * 1,841,041 lb/day) + (4.6x10-5 * 1,117,238 lb/day)
L = 320 lb/day

Note: These estimates agree with the Gradient/Geotrans figures by (+/-) 1 lb/day.

APPENDIX E-6
CALCULATION VERIFICATION
NIAGARA COUNTY REFUSE DISPOSAL
USGS SITE #81

DATA:

ZONE	Sum of all Components (ppb)	TOX (ppb)	TOC (ppb)
Overburden			
USGS Data (1985, 2 Wells)	76	N/A	N/A
NUS Data (1983, 5 wells)	9,000	N/A	N/A
EA Data (1987, 4 wells)	310,000	N/A	N/A
Bedrock			
No bedrock analyses were performed			

Calculations:

Best Estimate

Using the USGS data (wells within the fill area) yields:

Overburden

C = 310,000 ppb

Low Estimate

The low estimate of the contaminant concentration was derived using the NUS data.

Overburden

C = 9,000 ppb

High Estimate

Overburden

There is no basis in the data for this calculation

FLOW CALCULATIONS:

The overburden rates were determined by recharge rates

Recharge Parameters

Estimated Precipitation Rate	37 in/yr
Potential Evapotranspiration Rate	24-37 in/yr
Runoff	Unknown
Groundwater Inflow	Unknown (except into bedrock)
Area of Recharge to Landfill	348,480 ft^2

Recharge Estimates

Estimate	Rate (in/yr)	Recharge Area (ft^2)	Flow Rate (ft^3/day)
High	15	2175000	7400
Medium	9	2175000	4500
Low	3	2175000	1500

Estimated Flow Rates

	Estimated Flows	
Estimate	(gal/day)	(lb/day)
High	55,356	461,949
Medium	33,663	280,915
Low	11,221	93,638

Conversions Used: 1 ft^3 = 7.4806 gal(US)
1 gal(US) = 8.3450 lb

LOADING CALCULATIONS

Best Estimate:

L = C(Overburden) * Flow (Overburden)
L = (3.10x10-4 * 280,915 lb/day)
L = 87 lb/day

Low Estimate:

L = C(Overburden) * Flow (Overburden)
L = (9.00x10-6 * 93,638 lb/day)
L = 0.84 lb/day

High Estimate:

L = C(Overburden) * Flow (Overburden)
L = (3.10x10-4 * 461,949 lb/day)
L = 143 lb/day

Note: These estimates agree with the Gradient/Geotrans figures by (+/-) 1 lb/day, except for the "high" estimate, which was 3 lb/day higher than the value calculated by Gradient Corp. and Geotrans Inc..